From morphological computation to planning: insights from neuroethology

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While traditional neurobiology focuses on the nervous system, often as embedded in a laboratory environment, and often without reference to whole-animal behavior, the field of neuroethology has the broader goal of understanding how the nervous system subserves the behavior of the whole animal in its natural context. Consequently, the role of non-neuronal processes in some of the computations necessary to support complex behavior have been elucidated in exceptional detail in some key neuroethological model systems, particularly as this pertains to sensory signal processing prior to the entry of these signals into the nervous system. More recent work on understanding the mechanics of movement are providing similarly powerful examples of how energy efficiency and maneuverability can be accomplished with little or no neural involvement. These examples of morphological computation are suggestive of a continuum of timescales of adaptation to our environment, from bones to brains, according to the timescales of the regularities that need to be observed for survival.

Despite its reference to computation, there is significant distance between morphological computation and cognition. In this talk I suggest an approach from neuroethology that relates the two. We hypothesize that the capability to plan evolved through an exhaustion of the performance of reactive architectures when a certain relationship exists between the space over which an animal senses or represents its environment and the space over which it immediately moves. When the space within which objects can be sensed is far larger than the space over which the animal is immediately moving, reactive architectures suffer certain deficiencies. In these situations, deliberative architectures, while not essential, provide control solutions that are not obtainable through reactive approaches. Differential success of deliberative versus reactive approaches to control is one way in which selection pressures to develop brains capable of planning can occur. The hypothesis is anchored by some of our recent results that demonstrate matching between the sensing range of one active sensing system, a weakly electric fish that senses by means of a self-generated electric field, and its near-term movement capability. The observed hunting behaviors of this animal are highly reactive, since sensing is too costly to have extended far beyond the immediate space of movement. At the other extreme is the extraordinary planning capabilities of mammals such as primates, notable for their outstanding, long range visual systems. The forebrain, where planning appears to occur, has seen considerable elaboration in complexity in the mammals compared to phylogenetically nearest outgroups.